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(56) Documents cited
EP 0189027 A1 EP 0062517 A1 US 4255021 A
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(54) **Surgical laser having an annular beam**

(57) A laser 1 device, for use in ophthalmology, and optionally comprising a UV pulsed laser, has a beam distributor 3 therefor located across the path of the laser beam 2, the distributor 3 being an optical system having, on a common optical axis, e.g. two taper lenses 5, 6 and a telescopic objective 7, and being capable of transforming a parallel cylindrical beam from the laser source 1 into a variable-diameter D_2 annular beam 20 with a maximum diameter comparable with the diameter of a human cornea 4.

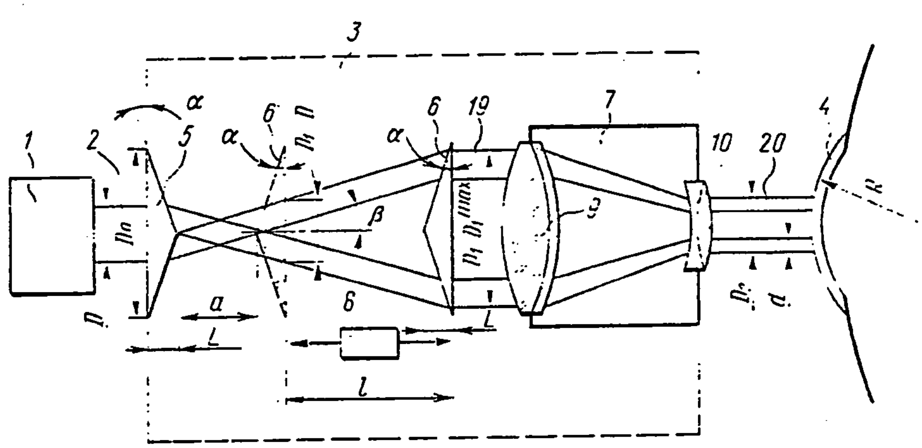

FIG.1

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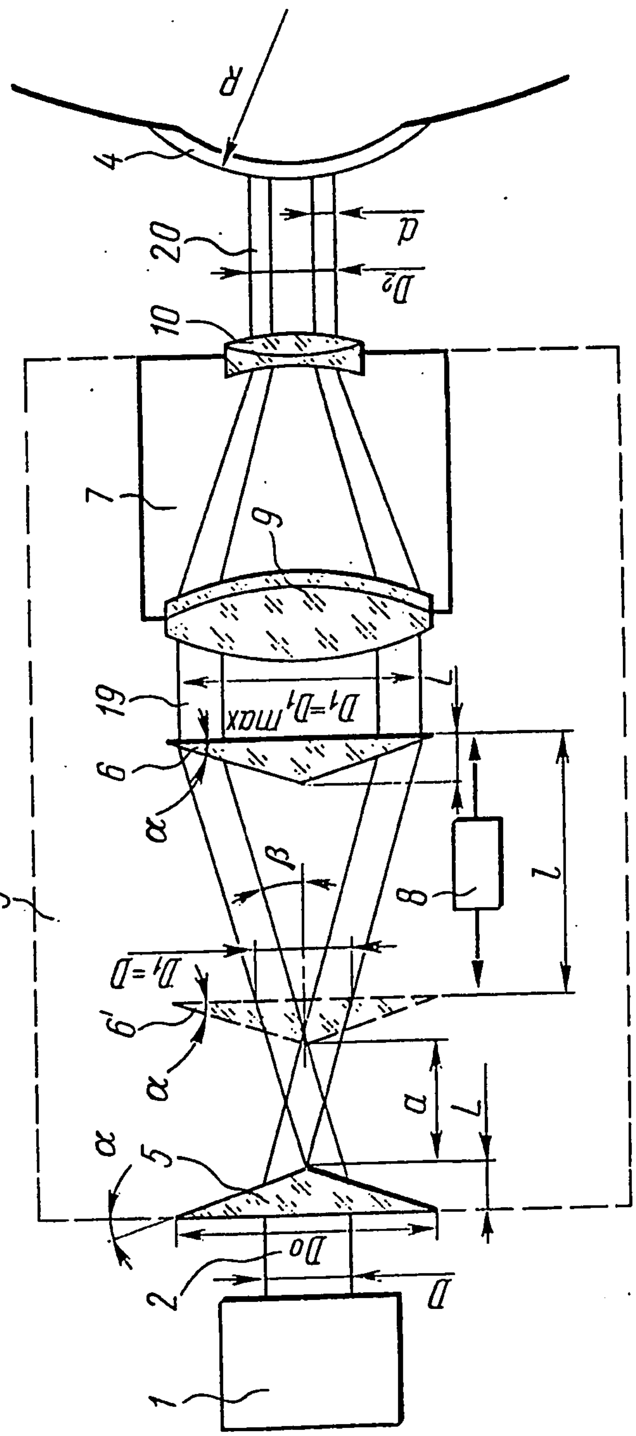


FIG.1

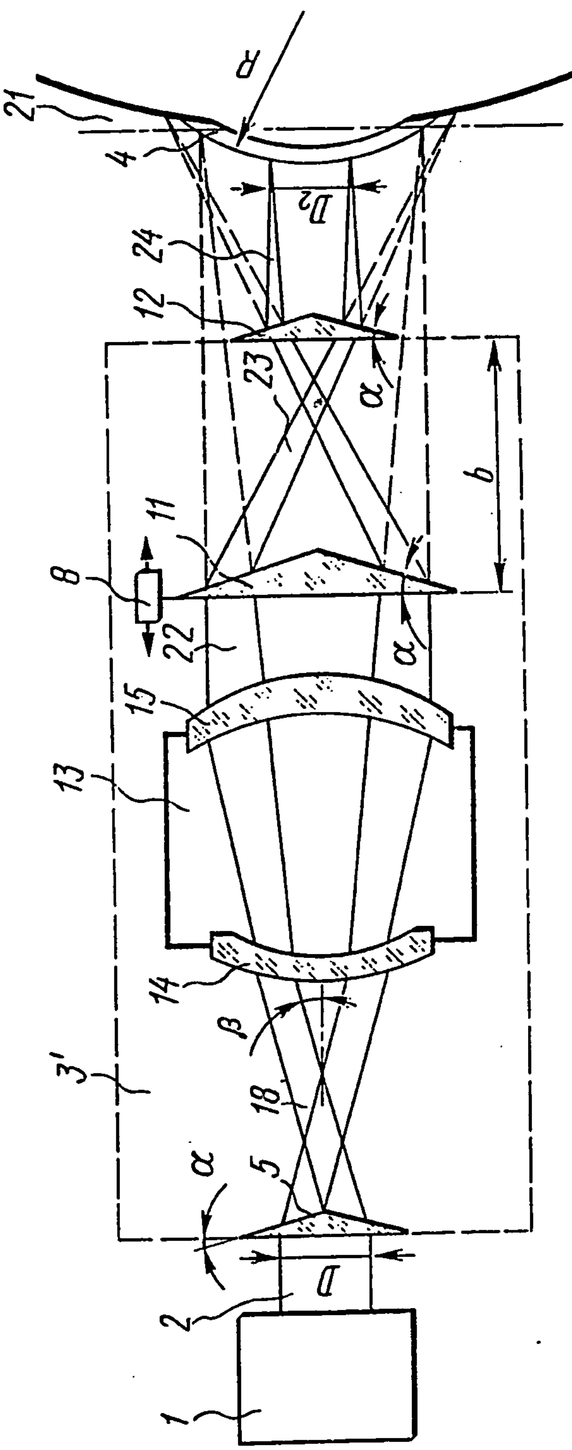


FIG.2

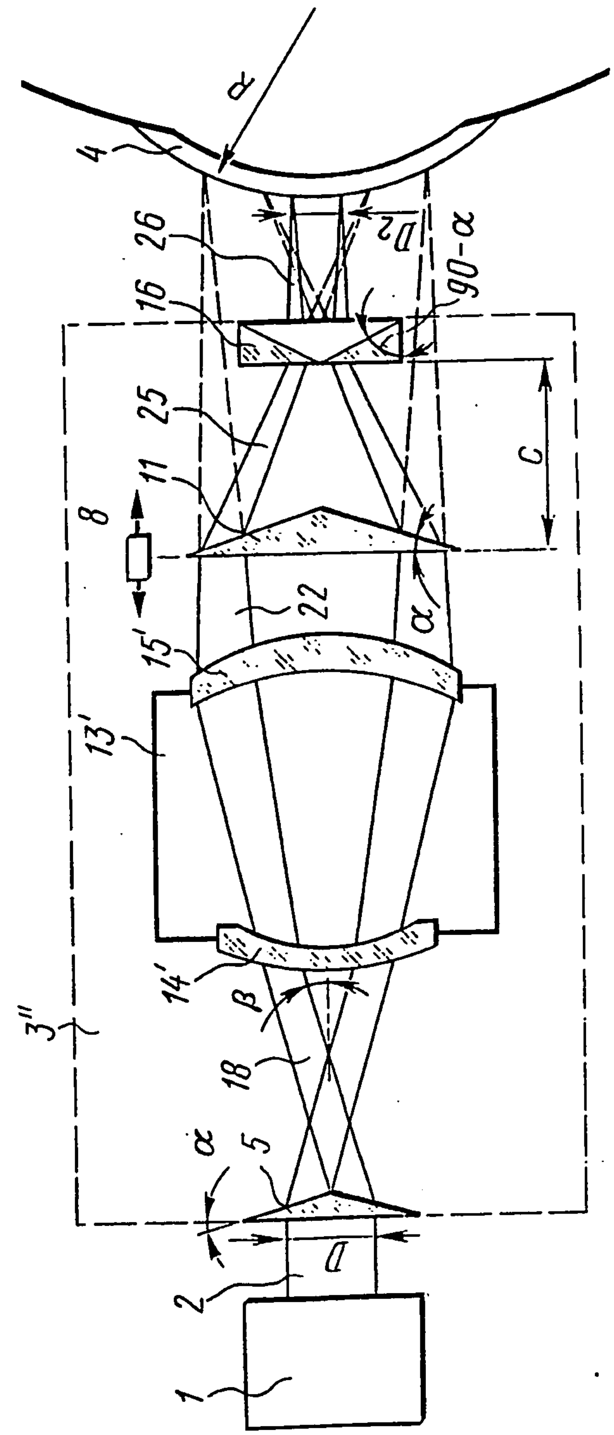
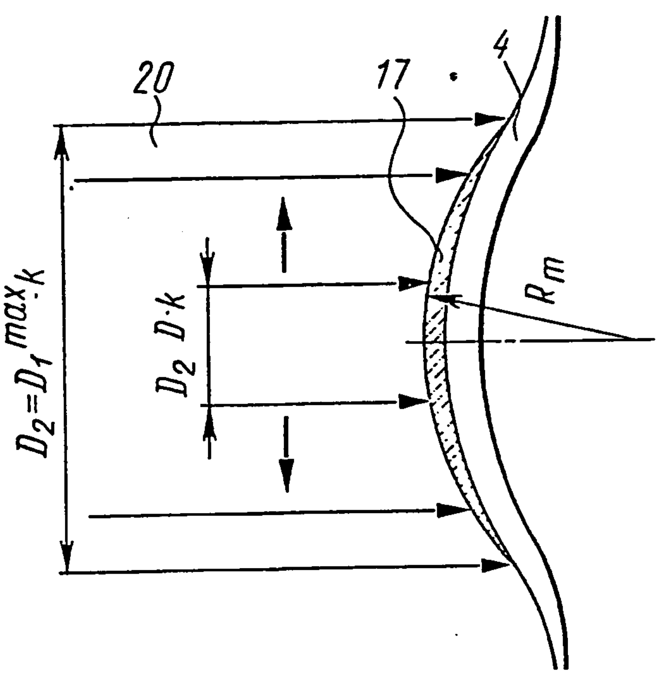
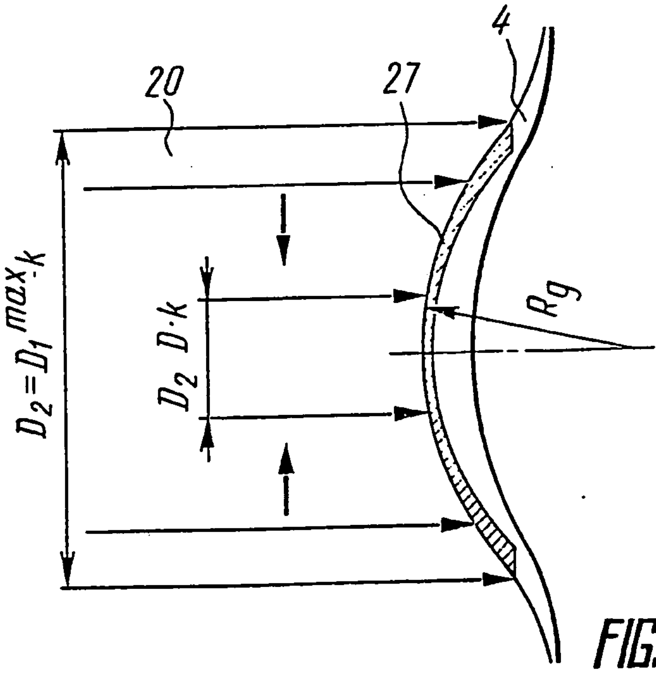


FIG.3



20
17
4
R_m
$D_2 \; D \cdot k$
$D_2 = D_1^{max} \cdot k$

FIG.4



4
20
27
R_g
$D_2 \; D \cdot k$
$D_2 = D_1^{max} \cdot k$

FIG.5

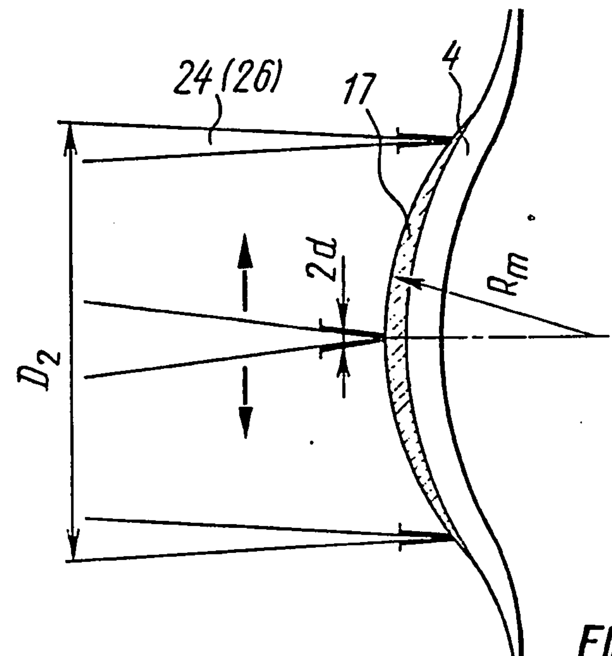


FIG.6

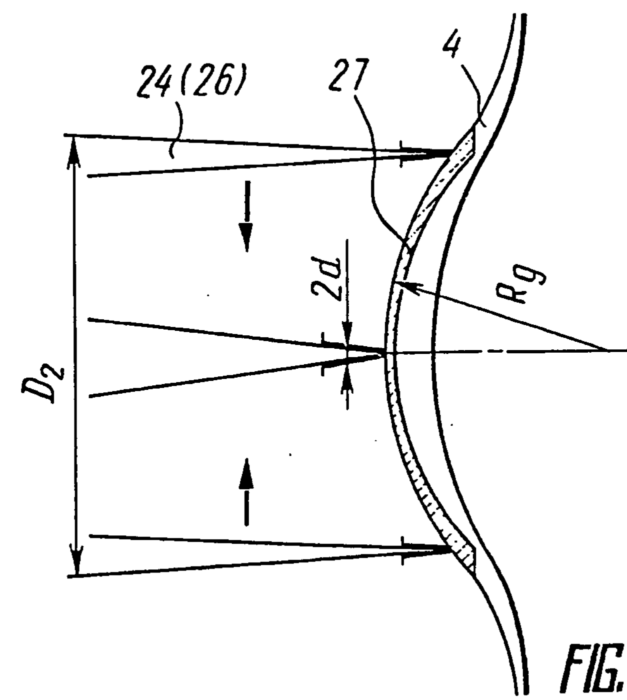


FIG.7

SURGICAL LASERS

The invention relates to medicine, i.e., to opthalmology and is concerned more specifically with devices for surgical treatment of ametropia (that is, myopia and hypermetropia).

One prior-art device for surgical treatment of ametropia is known to comprise a UV pulsed laser and a distributor of laser radiation energy density over the laser beam cross-sectional area, said distributor being placed across the path of the laser beam (cf. Report of the 'Centre Scientifique IBM', Paris, France, Document No. F104, 1986, K.Hanna et al., 'Excimer Laser Refractive Keratoplasty').

In the device mentioned above, the distributor of laser radiation energy density is in fact a rotary disk provided with a slit having a preestimated shape.

It is due to the effect of many laser pulses emitted with a preset ratio between the repetition frequency of radiation pulses and the slitted disk rotation frequency that the shape of the corneal surface is changed in order to correct ametropia.

However, only part of the cornea is exposed to momentary irradiation, said part depending on the shape of the slit and on its angular position at a given instant of time, which impedes the obtaining of smooth surfaces of a preset profile, since each radiation pulse removes a layer from the cornea having vertical walls, the shape of said layer following that of the slit. Hence the

required shape of the corneal surface is approximated by a stepped surface so that many shallow-depth layers are to be removed in order to obtain a smooth surface. This extends the operating time, i.e., hampers the conduction of an operative procedure, since it requires precise fixation of the patient's eyeball with respect to the laser beam for a prolonged period of time. Besides, the laser radiation energy is utilized but inefficiently, which also prolongs the operating time. The device is too complicated in manufacture, since the latter involves precision accuracy in making the slit and a mechanism for its rotation, accurate measurement of the slit angular position and time correlation between the position of said slit and the instant of laser pulse emission.

Another state-of-the-art device for surgical treatment of ametropia, in particular, myopia is described in 'Am. Journ. of Ophthalmology', v. 103, i.13, part II, M.B.McDonald et al., 'Refractive Surgery with the Excimer Laser', p.469, 1987.

In the device mentioned above the distributor of the density of laser radiation energy is made as a diaphragm placed across the path of the laser beam, the diameter of said diaphragm changing stepwise from pulse to pulse according to a computer program in such a manner that the shape of the corneal surface is changed for a required correction of myopia.

With the use of said device, as well as of the device described above, only part of the cornea is exposed to momentary irradiation, said part depending on the diaphragm diameter at a given instant of time, which impedes the obtaining of a smooth corneal surface; besides, many shallow-depth layers are to be removed from the corneal surface, which extends the operating time, since it requires precise fixation of the patient's eyeball with respect to the laser beam for a prolonged period of time. In addition, the laser radiation energy is utilized inefficiently, which also prolongs the operating time.

And one more prior-art device for surgical treatment of ametropia is known to comprise a UV pulsed laser and a distributor of laser radiation energy density over the laser beam cross-sectional area, said distributor being placed across the path of the laser beam (PCT/SU 88/00280).

In the device mentioned above the distributor of laser radiation energy density is shaped as an optic cell whose first and second optical windows disposed across the path of the laser beam, are made of a material transparent to laser radiation, and the inner surface of said optical windows is shaped as a second-order surface of revolution, that is, a paraboloid, hyperboloid, or sphere, while said optic cell is filled with a fluid medium capable of partially absor-

bing laser radiation. The abovesaid known device makes it possible to obtain a smooth corneal surface of a required shape.

However, the aforesaid device suffers from an inadequately efficient use of the laser radiation energy, since part of said radiation is absorbed by the medium contained in the optic cell, which prolongs the operating time.

In addition, to make the windows of the optic cell shaped as second-order surfaces of revolution is a technologically complicated task, since the windows of the optic cells must be made to a precision accuracy, while any departure from a preset shape results in an affected accuracy of a preset shape of the patient's cornea. Preoperative adjustment of the device is a sophisticated job as well.

It is a primary and essential object of the invention to provide a device for surgical treatment of ametropia featuring such a construction of the distributor of laser radiation energy density over the laser beam cross-sectional area that would make it possible to utilize most efficiently the energy of laser radiation and would at the same time be sufficiently simple in manufacture, which would enable one to manufacture the device with a precision accuracy and thus to cut down the operating time and to add to the accuracy of a preset shape of the corneal surface.

We have now discovered that the above problems can be overcome by the use of a distributor comprising laser-transparent lenses capable of focussing the beam into an annulus.

Thus, in a first aspect, there is provided a surgical laser device comprising a laser source and a beam distributor therefor, the beam distributor comprising a series of lenses capable of substantially transmitting all of the laser output directed thereon and focussing said output into a substantially annular beam.

The invention particularly comprises a first taper lens of substantially conical proportions upon which the beam can be centrally directed through the base. The result is a divergent annular beam. This can then be focussed as desired, particularly with regard the purpose to be served, preferably ablation of the cornea.

Suitable methods for focussing the resultant beam will be apparent to those skilled in the art, but it is preferred to use at least one further taper lens together with a telescopic objective to achieve a parallel beam.

It is particularly desirable to provide for the controlled movement of a second taper lens, to permit expansion and contraction of the final beam width, the preferred range being over the diameter of a human cornea.

In a preferred embodiment, there is provided a third taper lens, especially an inverted taper lens, with the telescopic objective being located between one and two. This permits focussing of the walls of the beam to a substantially 0 width at a focal plane, for greater accuracy and effect.

The essence of the invention resides in the fact that in a device for surgical treatment of ametropia, comprising a UV pulsed laser and a distributor of laser radiation energy density over the laser beam cross-sectional area, said distributor being placed across the beam path, according to the invention, the distributor of laser radiation energy density over the laser beam cross-sectional area is in fact an optical system, which incorporates arranged on a common optical axis at least two taper lenses and a telescopic objective, and is capable of transforming a parallel cylindrical laser radiation beam into a variable-diameter annular beam, the maximum diameter of which is comparable with the human's corneal diameter.

The distributor of laser radiation energy density of the proposed device for surgical treatment of ametropia may comprise two taper lenses having equal refractive angles and facing each other with their vertices, while the telescopic objective may be situated past the second taper lens as along the pathway of the radiation beam.

The distributor of laser radiation energy density may also comprise three taper lenses of which the second and third, as viewed along the radiation pathway, have equal refractive angles facing with their bases the laser, while the telescopic objective may be located between the first and second taper lenses as along the laser radiation path.

Moreover, the distributor of laser radiation energy density may comprise three taper lenses facing with their base laser, while the telescopic objective may be placed between the first and second lenses, as along the laser radiation path, and the third lens, as along the laser radiation path, may be in fact an inverted cone and have a refractive angle equal to $90° - \alpha$, where α denotes the refractive angle of the second lens as along the laser radiation path.

It is expedient, for all embodiments of the invention, that the second taper lens, as along the laser radiation path, be movable along the optical axis.

The device for surgical treatment of ametropia, according to the present invention, makes it possible to attain higher accuracy of a preset corneal shape due to a substantially cut down operating time. Such a curtailing of the operative time results from the fact that the entire radiation flux emitted by the laser acts upon the corneal surface being treated at each instant of time, while energy loss in the distributor of laser radiation energy density of the proposed device is minimized. Besides, the proposed device is readily amenable to adjustment for a preset amount of ametropia correction, said adjustment being effected by moving one of the taper lenses of said distributor with the aid of a stepped electric motor. To manufacture the taper lenses is a simpler technolo-

gical task as compared with the manufacture of the optic cell windows, which are in fact second-order surfaces of revolution; so the device, according to the invention, is simpler in manufacture and can be made to an adequate degree of accuracy.

In what follows the invention will be elucidated by a description of some specific exemplary embodiments thereof with reference to the accompanying drawings, wherein:

FIG. 1 is a diagrammatic view of a device for surgical treatment of ametropia, according to the invention, in its embodiment comprising two taper lenses;

FIG. 2 is a view of an embodiment of a device of FIG. 1, comprising three taper lenses;

FIG. 3 is a view of an embodiment of a device of FIG. 2, featuring its third lens shaped as an inverted cone;

FIG. 4 is a schematic view of a patient's eye at the stage of myopia treatment with the aid of the device shown in FIG. 1;

FIG. 5 is the same as in FIG. 4 for hypermetropia treatment;

FIG. 6 is a schematic view of a patient's eye at the stage of myopia treatment with the aid of the devices shown in FIG. 2 or FIG. 3; and

FIG. 7 is the same as in FIG. 6 for hypermetropia treatment.

The device for surgical treatment of ametropia, that is, myopia and hypermetropia, as shown in FIG. 1 comprises a UV pulsed laser 1 and a distributor 3 of the density of energy of radiation of the laser 1 over the cross-sectional area of a laser beam 2, said distributor 3 being placed across the path of the laser beam 2 so as to determine the diameter of the zone of surgery on a patient's cornea 4.

The distributor 3 of laser radiation energy density is in fact an optical system incorporating two taper lenses 5 and 6 arranged in tandem on a common optic axis, said lenses facing each other with their vertices and having equal refractive angles α, and a telescopic objective 7 situated past the second taper lens 6 as along the path of the radiation of the laser 1. All the optic elements mentioned above are made of a material transparent to laser radiation, e.g., of quartz. The second taper lens 6, as along the path of laser radiation, is traversable along the optical axis with the aid of a stepped electric motor 8 as in the embodiment described herein, and establishes, together with the first taper lens 5, a pancratic system. The telescopic objective 7 consists of a train of convergent lenses 9 and a train of divergent lenses 10, both being calculated with due account of minimized aberration and being in a general case a variable-magnification telescopic system.

FIG. 2 illustrates an embodiment of the herein-proposed device for surgical treatment of ametropia, wherein its distributor 3' of radiation energy density comprises three taper lenses 5, 11, 12, all of them facing with their bases the laser 1 and having equal interrefractive angles α and a telescopic objective 13 interposed between the first lens 5 and the second lens 11 as along the path of the radiation emitted by the laser 1. All optic elements in said embodiment of the device are also made of a material transparent to laser radiation, such as quartz, while the second taper lens 11 as along the path of laser radiation, is movable along the optical axis from the stepped electric motor 8. The telescopic objective 13 is constituted by a divergent lens 14 and a convergent lens 15, both being also calculated with allowance for minimized aberration.

FIG. 3 presents another embodiment of the herein-proposed device for surgical treatment of ametropia, wherein its distributor 3" of radiation energy density incorporates also three taper lenses 5, 11 and 16, all of them facing with their bases the laser 1, and a telescopic objective 13' comprised of a divergent lens 14' and a convergent lens 15', the parameters of said lenses being other than those of the elements of the telescopic lens 13 (FIG. 2), the telescopic objective 13' being interposed between the first taper lens 5 (FIG. 3) and

the second taper lens 11 as along the path of the radiation emitted by the laser 1. Unlike the embodiment of the device mentioned above, the third taper lens 16 features inverted conicity and its refractive angle equals $90° - \alpha$, where α is the refractive angle of the first taper lens 5 and the second taper lens 11 as along the path of laser radiation. All optic elements of the distributor 3" are likewise made of a material transparent to laser radiation, e.g., quartz, whereas the second taper lens as along the path of laser radiation is traversable along the optical axis with the aid of the stepped electric motor 8.

To select what an embodiment of the device for surgical treatment of ametropia is to be used depends on how producible is said device and on the requirement as for minimized aberration of the optical system of the device.

The device presented in FIG. 1 is more space-saving but needs higher accuracy of manufacture and is more difficult to adjust. The embodiments of the device as shown in FIGS 2 and 3 provide for higher accuracy of surgery, since they make use of focused radiation beams and feature the minimized aberration of their optical system.

The device depicted in FIG. 3 is more compact than that shown in FIG. 2 though provision of the inverted-conicity lens 16 therein complicates much its production technology.

The device for surgical treatment of ametropia, according to the invention, operates as follows.

Operation of the device as shown in FIG. 1 will hereinafter be considered with reference to treatment of myopia.

It is common knowledge that the corneal surface of a normal eye can be described by the equation of a paraboloid of revolution having a radius R of curvature.

The corneal surface 4 (FIGS 4, 6) of an eye affected by myopia is also described by the equation of a paraboloid of revolution having a radius R_m of curvature at its vertex less than in the case of a normal eye, i.e., $R_m < R$.

For surgical treatment of myopia a layer should be removed from the cornea, said layer being bounded by two parabolic surfaces differing in curvature and appearing as a hatched segment 17.

When treating myopia the parallel cylindrical radiation beam 2 emerging from the laser 1 (FIG. 1) and featuring its energy density uniformly distributed over the beam cross-sectional area (i.e., a circle with a diameter D), passes through the first taper lens 5 and is transformed into a cone-shaped beam 18 featuring the cone wall thickness equal to $D/2 \cdot \cos\beta$ and an included angle 2β of the cone-shaped beam, which depends on the refractive angle α and a refractive index 'n' of the taper

lens 5:

$$\sin\beta = (n\sqrt{1 - \sin^2\alpha} - \sqrt{1 - n^2\sin^2\alpha})\cdot\sin\alpha \quad (1)$$

Further on the laser beam 18, while passing through the second taper lens 6 having the same refractive angle α is transformed into an annular beam 19 featuring the thickness of annulus wall equal to D/2, while with the taper lens 6 steplessly moving along the optical axis by virtue of the stepped electric motor 8, the thus-forming annular beam smoothly changes its outside diameter D_1. Provision is made in the proposed embodiment of the device for a possibility of adjusting the value of D_1 within the limits of a ring having the minimum diameter D (that is, when the ring is transformed into a circle and the ring diameter equals zero) and a maximum-size ring having an outside diameter D_1^{max}, while the value of D_1 is related to the travelling of the taper lens 6 by the following equality:

$$D_1 = D + 2\ell\cdot tg\beta \quad , \qquad (2)$$

where ℓ - is the amount of displacement of the taper lens 6 from its zero position (shown at Ref. No.6' in FIG. 1), wherein D_1=D, said equality holding true when a distance 'a' between the vertices of the taper lenses 5 and 6 is selected according to the following expression:

$$a = \frac{D}{2tg\beta}\left(L - \frac{D_0 - D}{2}\,tg\alpha\right) \qquad (3)$$

where D_o is the diameter and L, the thickness of the taper lens 5.

Having passed through the second taper lens 6 the parallel radiation beam 19, whose cross-sectional area is annular-shaped, travels through the telescopic objective 7, in which said beam is transformed, with a magnification 'K', likewise into a parallel annular beam 20 having a variable outside diameter D_2 and a wall thickness 'd'. Then the beam 20 is directed immediately onto the cornea 4. The thickness 'd' of the wall of the beam 20 is changed by steplessly varying the distance between the lenses 9 and 10 of the telescopic objective 7.

Thus, $D_2=D_1 \cdot K$, where K is the magnification factor, which is less than unity, i.e., cross-sectional area of the beam 20 changes within the limits of the ring of a maximum diameter equal to $D_2=D_1^{max} \cdot K$ and a circle having a maximum diameter of $D_2 = D \cdot K$. In this case the diameter of $D_2 = D_1^{max} \cdot K$ is comparable with the diameter of the patient's cornea 4.

The thickness 'd' of the wall of the annular beam 20 is selected so as to suit the conditions of surgery and the parameters of the laser 1. It is desirable in this case to select the minimum possible value of 'd' with due account of the diffraction characteristics of the radiation energy density distributor 3.

When using the embodiment of the device, as shown in FIG. 2, for treatment of myopia the parallel beam 2 emerging from the laser 1 and featuring its energy density distributed uniformly over the cross-section having the diameter D passes, like in the preceding embodiment, through the first taper lens 5 and is transformed into the cone-shaped beam 18 having the cone wall thickness equal to D/2 cos β and an included angle 2β of the cone-shaped beam. Further on the beam 18, while passing through the train of the spherical lenses 14 and 15 that constitute the telescopic lens 13, is transformed into an annular beam 22 having a constant average diameter and a diminishing wall thickness, a focal plane 21 of said beam 22 intersecting the surface of the cornea 4 and being square with the optical axis of the device.

Then the annular beam 22, upon passing the telescopic objective 13, travels through a cone-shaped variable-magnification telescopic system constituted by the taper lenses 11 and 12, wherein said beam is first transformed into a cone-shaped beam 23 and then into an annular beam 24 having a variable diameter D_2 and a diminishing thickness 'd' of its wall.

The minimum cross-section of the beam 24 is essentially a circle with a diameter of 2d, the value of 'd' being selected so as to suit the conditions

of surgery and the parameters of the laser of the distributor 3'. The value of 'd' is selected to be the minimum possible and is largely determined by the diffraction characteristics of the distributor 3'. The diameter D_2 is changed to a required value which is attained by smoothly travelling the taper lens 11 along the optical axis with the aid of the stepped electric motor 8.

In the embodiment of the device shown in FIG. 3, operation of the radiation energy density distributor 3" differs from that of the distributor 3' of FIG. 2 in that the annular beam 22, upon passing through the telescopic objective 13', travels through a cone-shaped telescopic system established by the taper lenses 11 and 16, the latter lens having inverted conicity, wherein said beam is also transformed first into a cone-shaped beam 25, then into an annular beam 26 having a variable diameter and the thickness 'd' of its wall diminishing as along the radiation path. The minimum cross-section of said beam is also in fact a circle with a diameter of 2d, while the parameters of the beam 26 are also changed by smooth movement of the taper lens 11 along the optical axis with the aid of the stepped electric motor 8.

The distributor 3" of FIG. 3 is more compact than the distributor 3' of FIG. 2, since with the maximum values

of the diameter D_2^{max} of the annular beams 24 (FIG. 2) and 26 (FIG. 3) directed onto the cornea 4, a distance 'c' between the bases of the taper lenses 11 and 16 that constitute the cone-shaped telescopic system in the distributor 3", is at all times shorter than a distance 'b' between the bases of the lenses 11 and 12 in the distributor 3', that is, an inequality $c < b$ is always satisfied.

It is common knowledge that exposure of biological tissues to the effect of remote UV radiation results in ablation (evaporation) of such tissues, while the thickness of the tissue layer being ablated is in direct proportion to the energy density within a certain range of the radiation energy density values.

In the course of surgery, interaction of the effective laser radiation beam 20 (FIG. 1) with the cornea 4 results in removal of the segment 17 (FIG. 4). The similar segment 17 (FIG. 6) is removed also due to interaction of the beams 24 (FIG. 2) and 26 (FIG. 3) with the cornea 4. Irradiation starts from the central zone of the cornea 4 with the maximum diameter of the effective radiation beam and is carried out in such a manner that the exposure time is reduced as the diameter of the effective beam increases. Appropriately selected irradiation conditions results in removal of the segment 17 (FIGS 4

and 6) of the cornea 4, which is bounded by two parabolic surfaces of revolution of which one is the myopia-affected corneal surface, while the other is the surface of the cornea 4 after its having been exposed to the effect of the radiation of the laser 1 (FIGS 1, 2, 3). Irradiation is carried out prior to elimination of myopia (i.e., the hatched segment 17 in FIGS 4, 6).

The corneal surface of a hypermetropic eye is described by the equation of a paraboloid of revolution having a radius R_g of curvature at the vertex exceeding that in the case of a normal eye, i.e., $R_g > R$. For surgical treatment of hypermetropia a layer should be removed from the cornea 4, which is bounded by two different-curvature parabolic surfaces, i.e., a hatched segment 27 (FIGS 5 and 7). Surgical treatment of hypermetropia is carried out in a way similar to that described for myopia, the sole difference residing in the fact that irradiation of the cornea 4 starts from its periphery, with the maximum diameter of the effective radiation beam, and is performed with gradually reduced both the effective beam diameter and the irradiation time.

To promote understanding of the essence of the present invention, given below is a specific exemplary embodiment thereof.

An embodiment of the device for surgical treatment of ametropia, according to the invention, as shown in FIG. 3 has been manufactured and tested. In order to alter the eye refraction of a test rabbit use was made of the radiation of the excimer laser 1 on A+F molecules and a wavelength of 193 nm, shaped into a parallel cylindrical beam having a diameter D = 6 mm. All static elements of the distributor 3" of radiation energy density were made of optic quartz (n = 1.559). The first taper lens 5 having a convex surface (i.e., direct conicity) and a refractive angle $\alpha = 10°$ and the third taper lens 16 having inverted conicity and a refractive angle $90° - \alpha^* = 76°$ were fixed stationary, whereas the second taper lens 11 having direct conicity and a refractive angle $\alpha^* = 14°$ travelled along the optical axis for a distance $\ell = 150$ mm, which enabled the value of D_2 to be adjusted within 8 and 0.5 mm, with the ring wall thickness d = 0.25 mm = const in the plane of the radiation effect.

The repetition frequency of the radiation pulses emitted by the laser 1 equalled 15 Hz, the pulse energy changing within 100 and 300 mJ. As a result of surgical procedures on 16 eyes of 8 experimental rabbits there was attained an alteration of the corneal refraction within 0.5 and 5 dioptres depending on the parameters of the radiation effect applied.

Practical application of the device, according to the invention, makes it possible to enhance the accuracy of a preset shape of the treated corneal surface eight- to tenfold as compared with the similar device having a changeable diaphragm, to cut down the operating time seven-to eight-fold, as against the aforesaid device and three- to four-fold as compared with the device, wherein the distributor of radiation energy density is in fact an optic cell.

Such an enhancement of the accuracy of a preset shape of the treated corneal surface occurs largely due to a substantially curtailed operating time, which in turn results from the fact that the entire radiant flux emerging from the laser 1 acts on the surface of the cornea 4 being treated at every instant of time.

M&C FOLIO: 230P60473 WANGDOC: 0280D

CLAIMS

1. A surgical laser device comprising a laser source and a beam distributor therefor, the beam distributor comprising a series of lenses capable of substantially transmitting all of the laser output directed thereon and focussing said output into a substantially annular beam.

2. A device according to claim 1, the distributor comprising at least one taper lens.

3. A device according to claim 1 or 2, wherein the beam is focussed substantially parallel.

4. A device according to claim 1, 2 or 3, the distributor further comprising a telescopic objective.

5. A device according to any preceding claim, comprising 2 or 3 taper lenses.

6. A device according to any preceding claim, wherein the width of the beam wall diminishes away from the final element of the distributor to a focal plane.

7. A device according to any preceding claim wherein the width of the annular beam is adjustable between at least a range wherein the distance between walls of the beam is substantially 0 and an overall diameter of about the diameter of the cornea of a human eye.

8. A device according to any preceding claim using pulsed UV laser light.

9. A surgical device comprising a UV pulsed laser and a beam distributor therefor located across the beam path, the distributor having, on a common optical axis, at least two taper lenses and a telescopic objective, and being capable of transforming a parallel cylindrical laser radiation beam to a maximum value comparable with the diameter of a patient's cornea.

10. A device according to any preceding Claim, wherein the distributor comprises two taper lenses having equal refractive angles and with vertices facing each other, the telescopic objective being distal to the second lens along the laser path.

11. A device according to any of Claims 1 to 9, wherein the distributor comprises three taper lenses, bases to the laser source, the second and third lenses distal to the source having equal refractive angles, the telescopic objective being interposed between the first and second lenses.

12. A device according to any of Claims 1 to 9, wherein the distributor comprises three taper lenses, bases to the laser source, the telescopic objective being interposed between first and second lenses distal to the source, the third lens being shaped as an inverted cone and having a refractive angle of $90^{o}-\alpha$, where α denotes the refractive angle of the second lens.

13. A device according to any preceding Claim and comprising at least 2 taper lenses, the second lens being movable along the optical axis.

14. A laser device, comprising at least one taper lens, substantially as described hereinbefore with particular reference to any of the accompanying Figures 1 - 3.

Published 1990 at The Patent Office.S[illegible] may be obtained from The Patent Office Sales Branch, St Mary Cray [illegible] Mary Cray. Kent. Con. 1/87